2.—The Largest Known Australite and Three Smaller Specimens from Warralakin, Western Australia

By George Baker*

Manuscript received—19th December, 1960

A large oval australite core recently discovered near Warralakin, Western Australia, is incomplete because of artificial fracturing and relatively severe natural weathering but it is nevertheless the largest australite so far brought to the notice of the scientific world. Even with the fracture fragments missing, the specimen weighs 20 grams more than the heaviest australite recorded to date. It weighs 238 grams; its weight at the time of landing upon the earth's surface has been estimated as approximately 280 grams. Reconstruction of the approximate primary shape of this australite reveals that about 35 per cent. of its original bulk was lost by ablation from aerodynamic friction during passage through the earth's atmosphere at high velocities.

Three smaller australites subsequently found in the same general area, six to nine miles south of the Warralakin-Warrachuppin railway line, are briefly described.

Introduction

The largest australite so far discovered was unearthed during post-hole digging operations which penetrated to a depth of 20 inches in soil, approximately 16 chains north of the south-west corner of Block 301, 9.6 miles S.S.E. of Warralakin Siding, Yilgarn Area, Western Australia (Fig. 1). The geographical position of this locality is 31° 08′ 25″ S. and 118° 41′ 21″ E. The specimen was found in August, 1957—previously to which no other australites had been observed in this area.

Warralakin is 175 miles E.N.E. of Perth, Western Australia, and is on the Wyalkatchem-Southern Cross railway loop-line.

The specimen was recovered in a slightly chipped and weathered condition by Messrs. D. S. and A. V. Poole on the property "Coppin Rock" near Warralakin. The slight chipping resulted from damage by the post-hole digger. Screening of the soil from the post-hole failed to recover the detached fragments. Unfortunately a large piece was subsequently fractured from the end of the specimen with a cold chisel and lost. Even without this fragment, however, the specimen constitutes the largest australite known to science. In the unbroken condition it would have been approximately 50 grams heavier than the previously recorded (Fenner 1955) heaviest australite.

This australite is lodged in the geological collection (Reg. No. 8925) of the School of Mines of Western Australia, Kalgoorlie, to which institution it was donated by Mr. R. W. Poole (of Gold Mines of Kalgoorlie), a brother of the discoverers.

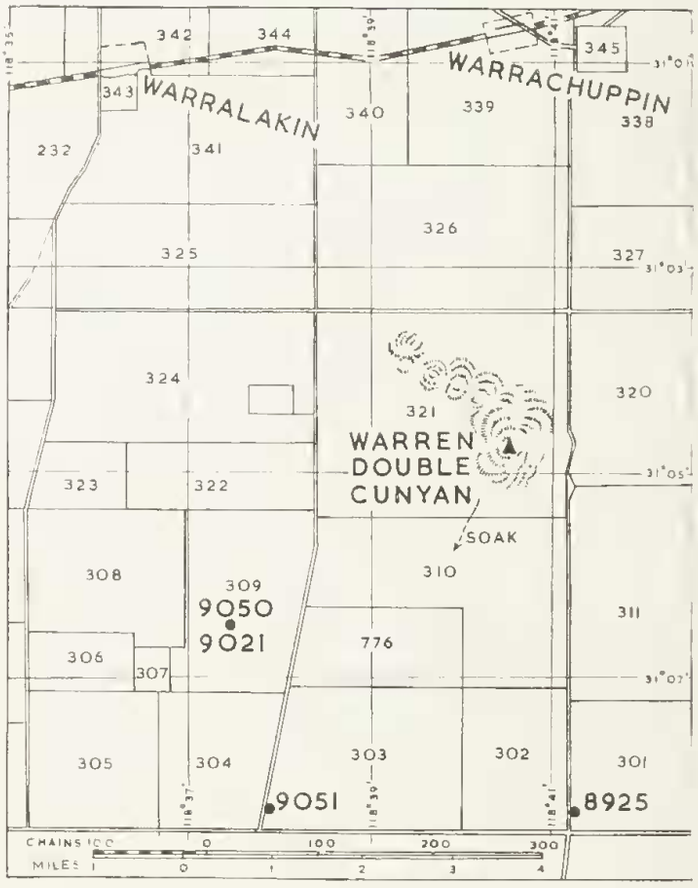

Fig. 1.—Locality map of the area south of the Warralakin-Warrachuppin railway line, Yilgarn Area, Western Australia, showing sites (full circles) of recently discovered australites. The large figures are the registered numbers of the australites in the geological collection of the School of Mines of Western Australia, Kalgoorlie.

The precise depth and orientation of the specimen in the soil could not be noted at the time of discovery, but detailed inspection of all surfaces and of the clay lodged in pits on them leads to the conclusion that the posterior surface lay downwards in the soil. The clay on the posterior surface was redder in colour due to more ironstaining, whilst that on the anterior surface was biscuit-coloured to almost white due to leaching, and the redder coloured clay on the posterior surface was rather more firmly cemented into pits and narrow flow lines. In

* C.S.I.R.O., Mineragraphic Investigations, c/o Geology Department, University of Melbourne, Parkville, N.2, Victoria.

the vicinity of the find, the area is relatively well-timbered, the surface is sandy with a few pebbles brought up by the roots of fallen trees.

The soil in which the specimen was found is of the "sand plain" type. In Western Australia, this is often a leached "A" horizon but, irrespective of the initial origin of the sand, it has usually been wind-drifted to a greater or lesser extent. It can be quite confidently stated that this large australite occurred at shallow depth in wind-blown sandy soil.

The deduced position of rest of the australite, i.e., with its anterior surface upwards, is the reverse to its position of aerodynamically stable orientation during earthward flight. Nevertheless this is the stable position of rest on the earth's surface, just as for the majority of australites exposed on the surface for which this position was observed on discovery. The stable position of rest was either attained immediately after striking the ground, or resulted subsequently when specimens were moved by transporting agents after landing.

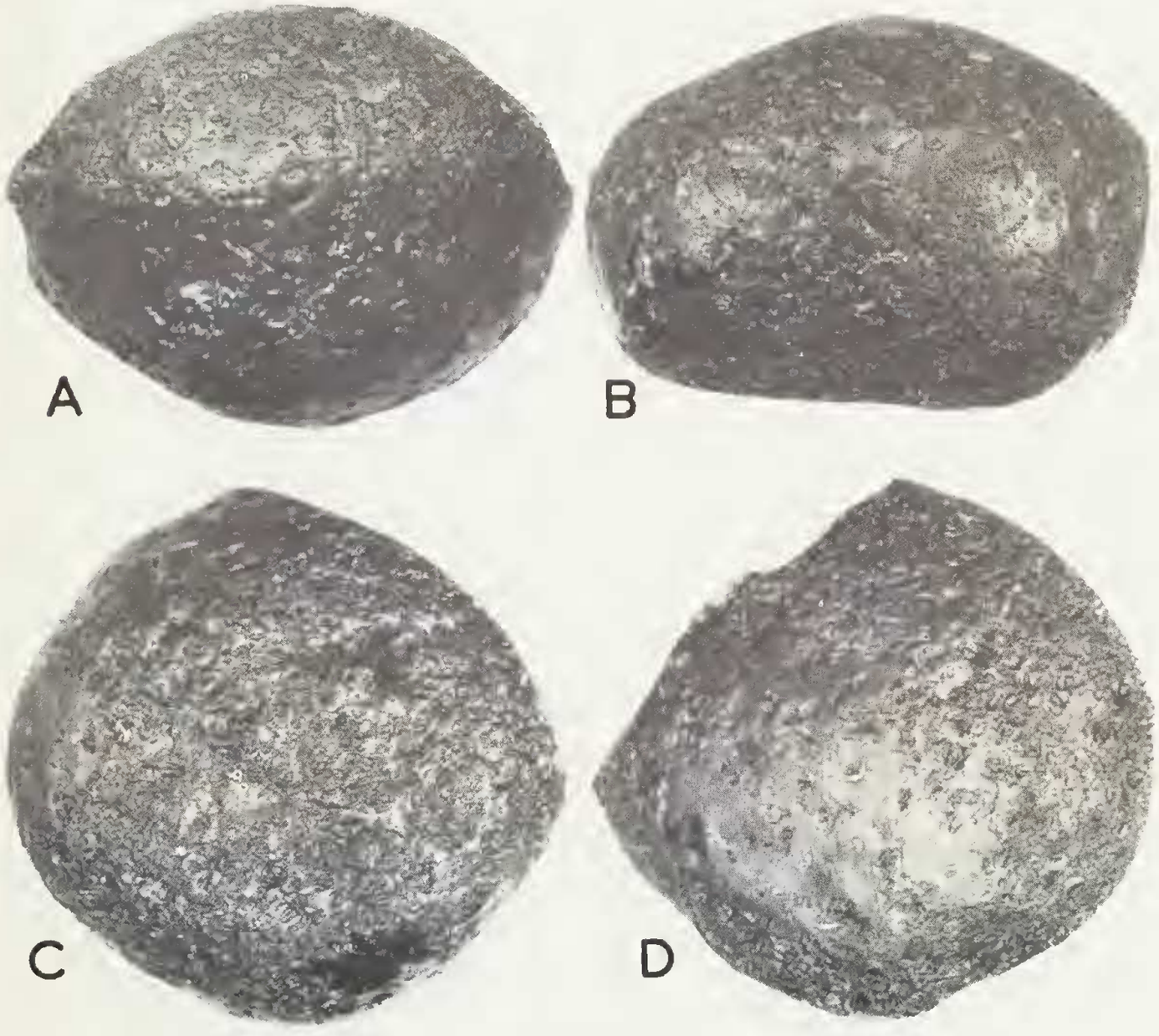

PLATE I

The largest known australite (Reg. 8925, geological collection, School of Mines of Western Australia, Kalgoorlie). From south-west corner of Block 301, 9.6 miles S.S.E. of Warralakin Siding, Western Australia.

Figs. A to D—showing etched "bruise-marks", a few of which resemble "höfchen" and "tischschen", on an oval australite core. A = end-on view across shortest diameter; posterior surface uppermost: rim poorly preserved (×1.16). B = side view across largest diameter; posterior surface uppermost; equatorial zone at right-hand end relatively well preserved (×1.10). C = anterior surface (×1.10). D = posterior surface (×1.10).

(Photographs by K. L. Williams.)

Description of Specimen

As submitted for examination, the weathered specimen revealed a small quantity of light buff-coloured to reddish-brown lateritic sandy soil partially cemented and partly jammed into shallow pits and lunate to circular shallow grooves on all surfaces, except the newly exposed (artificially fractured) surface. It was necessary to remove all secondary material prior to determining the specific gravity of the australite.

The weathered surface has a dull lustre and reveals occasional poorly pronounced "höfchen" and "tischschen" structures brought out by differential solution-etching by soil solutions. Rare, fine flow lines occur on parts of the surface, while only a few straight, slightly deeper grooves with parallel walls are present in one place. Many of the markings on the posterior and anterior surfaces of the specimen resemble chatter-marks brought about by collisional bruising, but since the australite was found in a milieu where natural agencies likely to have caused these features are apparently wanting, the possibility arises that the marks may have been due to aboriginal activities (e.g. use as a pounding stone, etc.), although this is difficult to prove.

The broken surface reveals the highly vitreous lustre and conchoidal fracture with subsidiary ripple fracture pattern that is so characteristic of freshly fractured tektite glass. Up to three dozen minute internal bubbles can be detected on the fractured surface with the aid of a 10× hand lens. The area of the fractured surface is approximately 12.5 cm^2, and if the internal bubbles are maintained in this distribution throughout the interior of the large australite, they could partly account for the specific gravity of the tektite glass as a whole being lower than usual for australites from the western portions of the Australian tektite strewnfield. These bubbles are more or less spherical in shape, and range from 0.25 mm to nearly 0.75 mm in diameter.

A rim (cf. Baker 1959, p. 39) is just discernible around most of the periphery of the specimen (see Plate I, Figs. A and B), and is sufficiently pronounced to aid in discriminating between the anterior and posterior surfaces of the australite.

The tektite glass is jet black and opaque in reflected light for the specimen in bulk, but yellowish bottle-green and translucent in transmitted light on the thinner edges of the fractured surface and in small splinters detached for refractive index determinations.

Dimensions, Weight and Specific Gravity

The specimen is 42 mm in depth (= thickness) and 62.5 mm in width as determined from the non-fractured portions of the australite. Its present length is 65 mm, but the original length (on reconstruction of the fractured form) was approximately 70 to 72 mm. It is thus an oval australite core. It weighs 238.00 grams and has a specific gravity value of 2.409 as determined in distilled water (T_{H_2O} = 12.8° C.) on a Mettler K-type balance. The specific gravity is approximately that of the mean specific gravity value determined for 1,086 specimens of australites (Baker and Forster 1943, p. 403), but is significantly lower than the general run of specific gravity values for australites from the western half of Australia, evidently because of its content of small bubbles.

The volume of the cleaned specimen is 98.8 cm^3. Reconstruction of the unbroken (but weathered) form reveals that approximately one ninth was removed by artificial fracturing, so that the specimen as found would have weighed about 265 grams. It has not been possible to reconstruct the specimen accurately enough to ascertain its size as it would have been on first landing upon the earth's surface from an extra-terrestrial source, but an approximate estimate of the amount weathered from this large oval australite core indicates that in the perfectly preserved state, the original weight would have been in the vicinity of 280 grams.

Australites weighing over 200 grams are extremely rare, and only two others are known. One, weighing 218 grams, was found at Lake Yealering, Western Australia (Fenner 1955), the geographical position of which is approximately 32° S. and 118° E., the other came from Karoonda, South Australia (Fenner 1955), at 35° S. and 140° E. and it weighs 208.9 grams. The Lake Yealering specimen is lodged in the collection of the Western Australian Museum in Perth, Western Australia, and the Karoonda specimen is in the South Australian Museum collection in Adelaide, South Australia.

Only eleven specimens are known that weigh over 100 grams and under 200 grams. Seven of these are recorded by Fenner (1955, pp. 90-91); the other four are:—a boat-shaped form of 141.63 grams weight from Port Campbell, Victoria (Reg. No. 11402, National Museum of Victoria collection), a round core of 135.16 grams weight from Gymbower near Goroke, Western District of Victoria (National Museum of Victoria collection), a round core of 111.25 grams weight from Lake Wallace near Edenhope, Victoria (Reg. No. E1986, National Museum of Victoria collection), and a boat-shaped form of 107.46 grams weight from near Narembeen, Western Australia (Reg. No. 8950, geological collection, School of Mines of Western Australia, Kalgoorlie).

Refractive Index and Estimated Silica Content

The refractive index of the glass varies according to the chemical composition of different internal schlieren, but does not show a wide range in the small fragments examined. Values obtained by the Immersion Method using monochromatic (Na) light and employing microscopic fragments removed from the freshly fractured surface of the specimen by light pressure flaking, showed a range from:—

$$n_{Na} = 1.504 \text{ to } n_{Na} = 1.506$$

The specific refractivity (k) of the glass, determined from the relationship $k = n - 1/d$ (where n = the refractive index, and d = the specific gravity of the specimen), ranges from 0.2092 to 0.2100, according to the composition of the different schlieren.

From the Silica-Specific Gravity and the Silica-Refractive Index graphs for tektites generally (see Barnes 1940; Baker 1959), the silica content of the specimen is estimated to be approximately 74 per cent. In view of the possibility that the content of small internal bubbles lowers the specific gravity of this specimen, however, both the silica content and the specific refractivity may be slightly different from the estimated values, but the silica content is likely to be no more than one or two per cent. lower.

Curvature of Surfaces

Silhouette traces of the weathered specimen reveal that arcs of curvature across the shortest diameter of the australite are:

$$R_B = 34.5 \text{ mm, and } R_F = 31.5 \text{ mm,}$$

where R_B = the radius of curvature of the posterior (back) surface and R_F = the radius of curvature of the anterior (front) surface. Across the longer diameter, the radii of curvature are $R_B = 40.9$ mm and $R_F = 44.1$ mm, but constructed circles do not fit as accurately to the arcs of curvature in this direction as to the surface curvature across the shorter diameter.

The original form, prior to modification by (i) ablation arising from aerodynamic friction during atmospheric flight, (ii) weathering by subaerial agents, and (iii) artificial fracturing after the specimen was collected, is estimated to have been an ellipsoid of revolution measuring approximately 7 cms × 7 cms × 8 cms in size. The depth of ablation in the stagnation point region (i.e. at the front pole of the specimen as aligned in aerodynamically stable orientation) was approximately 2.4 cms, and the overall amount ablated from the surface projected in the line of flight (i.e. the anterior surface) totalled about 60 cm^3 in volume. Some 35 per cent. of the original form was thus lost during transit at ultrasupersonic speeds through the earth's atmosphere, by the processes arising from aerodynamic friction. This is a relatively low percentage loss compared with many smaller australites for which the range in amount of glass removed by ablation and fusion stripping plus flange shedding is from 32 per cent. to 98 per cent., with an average loss (for 65 specimens) of 50.5 per cent. (cf. Baker 1961*a*, Tables 4, 9 and 11). It is also much lower than the percentage loss range (61 to 96 per cent.) by ablation of ten larger, well-preserved australite cores from Port Campbell, Victoria (cf. Baker 1961*a*, Table 13).

Smaller Australites

Of the three smaller australites subsequently found some three and a half miles west and four and a half miles north-west of the site of the largest australite, two are boat-shaped and one oval-shaped. They and the largest australite were recovered from within an area of approximately nine square miles (Fig. 1).

Boat-shaped Form

The largest of the three smaller forms was found late in 1958 by Mr. D. S. Poole on Block 309 on H. M. Poole's property "Devon." This is 7.2 miles east of south from Warralakin Siding, or 31° 06′ 36″ S. and 118° 38′ 34″ E. Here the surface consists of residual gravel resulting from partial exposure of the laterite horizon.

The specimen was presented by Messrs. D. S. and R. H. Poole to the School of Mines of Western Australia, Kalgoorlie (Reg. No. 9021). Its dimensions are 38.5 mm long, 27.5 mm wide, and 16.5 mm deep (= thick). It weighs 22.227 grams, and its specific gravity as determined in distilled water (T_{H_2O} = 13° C.) on a chemical balance is 2.425.

The specimen reveals a fairly well-defined rim separating the pitted and flow-lined posterior surface from the finely etch-pitted anterior surface. All structures on the australite, however, have been considerably modified by solution-etching, although the specimen is generally rather better preserved than the large australite described above. The boat-shaped outline of the specimen from front and back aspects is somewhat irregular (Plate II, Figs. A and B) due to erosion.

Portions of the flow-swirled central region of the posterior surface (Plate II, Fig. B) have been partly accentuated but some areas have been partly destroyed by solution-etching. Its general characteristics, however, are similar to the primary flow swirls on the posterior surfaces of better preserved australites.

In side- and end-on aspects, the outline is approximately that of a biconvex lens which has one diameter greater than the diameter at right angles. The radii of curvature across the shorter diameter (= width) are R_B = 16.8 mm and R_F = 17.2 mm, with the arcs of curvature fitting those of constructed circles with these radii. The radii of curvature along the larger diameter (= length) are approximately R_B = 32.9 mm, and R_F = 25.9 mm, but these two arcs of curvature do not conform accurately to the arcs of curvature of constructed circles with these radii, being rather flatter in the polar regions and steeper towards the rim of the specimen.

Oval Core

An eroded oval australite core was found by Mr. A. T. Miles with its anterior surface upwards on 9th October, 1960. It was exposed on the gravelly surface of an area that slopes gently northward near the site of Reg. No. 9021 (Fig. 1). The specimen is now in the collection of the School of Mines of Western Australia, Kalgoorlie (Reg. No. 9050).

It weighs 7.102 grams and its specific gravity is 2.431 (T_{H_2O} = 15.5° C.). The longer diameter measures 22 mm, the shorter 18 mm and the depth (= thickness) is 14 mm.

All surfaces reveal the effects of solution-etching and the sculpture pattern consists principally of small pits 0.2 mm across, ranging up to a few larger pits 3.0 mm across, mostly on the posterior surface. The larger pits reveal a few smaller pits and etched out flow lines on their walls. Where the larger pits are crowded together, sharp ridges separate one pit from its neighbour, and these parts of the surface resemble that of hammered metal.

PLATE II

A boat-shaped australite found 4½ miles south-east of the large oval australite core shown in Plate I (Reg. No. 9021, geological collection, School of Mines of Western Australia, Kalgoorlie).

A = anterior surface showing fine etch pitting (×2.57). B = posterior surface with weathered and etched flow swirl surrounded by bubble pits modified by etching (×2.57).

(Photographs by K. L. Williams.)

A flaked equatorial zone is detectible but rather poorly preserved. It shows a few complexly contorted flow lines that have been exposed and accentuated by solution-etching. These are the surface expressions of an internal schlieren structure brought into prominence on the level to which weathering has advanced. Flaking around the equatorial zone has resulted in the specimen appearing like a conical core in side aspect.

Smaller Boat-shaped Form

Like all the other specimens from this area, the smaller boat-shaped form reveals no evidence that would indicate the former existence of a circumferential flange. If ever present, the flange has been completely removed, either by shedding during flight, or subsequently by subaerial erosion, and erosion has further modified the equatorial region and the posterior and anterior surfaces of the specimen.

It was found with the anterior surface facing upwards by Mr. D. S. Poole on 10th October, 1960, on the roadside between Block 303 and Block 304, approximately 22 chains from the south-west corner of Block 303 (Fig. 1.). Its registered number is 9051 in the collection of the School of Mines of Western Australia, Kalgoorlie, and it was discovered on top of the ground in gravel country similar to that on which Reg. Nos. 9021 and 9050 were found. The geographical location of the specimen is approximately 31° 08′ 21″ S. and 118° 37′ 58″ E.

Its weight is 5.9115 grams and its specific gravity is 2.433 (T_{H_2O} 15.5° C.). The measurements of the specimen are 26 mm long, 17 mm wide and 10 mm deep.

An old fracture surface at one end of the specimen is as prominently sculptured by weathering (mainly solution-etching) as are the posterior and anterior surfaces.

The rim separating the posterior from the anterior surface is detectible in places around the periphery of the specimen. Both surfaces reveal flow lines which represent the "outcrops" of an internal schlieren pattern that trends generally parallel with the outline of the form. Some of the smaller pits on both surfaces are evidently etch pits resulting from weathering, but several deeper rounded pits 1 mm across and elongated pits 2 × 1 mm in size are either overdeepened, originally superficial bubble pits or else internal bubbles exposed during the process of weathering.

Summary and Conclusions

The four australites recovered from the area south of the Warralakin-Warrachuppin railway line in Western Australia have all been modified by subaerial erosion to such an extent that their volumes on first landing on the earth's surface cannot be accurately determined. Their sculpture patterns are largely a result of weathering, more particularly by the process of solution-etching in sandy soils.

In borrow pits and the banks of dams in the district, the soil profile shows a variable thickness of sandy soil passing downward into a zone of discrete laterite nodules, and thence, in a depth of a foot or so, into compact laterite. The variable thickness of the sandy soil is partly attributable to wind, and, in some places, partly to rainwash. The largest specimen (Reg. No. 8925) was found where the wind-drifted sand is thicker than usual, and at this locality the 20″ deep postholes barely entered the nodular laterite zone. This specimen could well have been exposed at one time and reburied under drifted sand. By contrast, two of the smaller specimens (Reg Nos. 9021 and 9050) that were found within four chains of each other, occurred right at the surface (gibber-plain type) in an area where partial stripping of the finer soil constituents had exposed nodules of laterite, among which the two australites were exposed to view. The fourth specimen (Reg. No. 9051) occurred on a gravelly, similarly stripped area. On gravelly slopes in this area, more thorough soil stripping down to the duricrust surface could readily result in removal of both lateritic nodules and australites and their transportation to flat-lying areas where re-burial in sandy soil is not improbable.

There is little doubt that these australites are post-laterite in age and their recovery from the overlying soils points to their recent age on earth (cf. Baker 1961*b*). Their surface sculpture is largely a result of weathering, whereby subaerial agents have reduced the sizes of the original specimens and developed structures that are a manifestation of their usually complex internal streakiness.

Acknowledgments

The author is indebted to W. H. Cleverly, B.A., B.Sc., head of the Geology Department, School of Mines of Western Australia, Kalgoorlie, for kindly submitting the australites for examination, and for obtaining details of their mode of occurrence and precise localities of discovery.

I am also grateful to Professor Rex T. Prider for communicating the paper through his membership of the Royal Society of Western Australia.

References

Baker, G. (1959).—Tektites. *Mem. Nat. Mus. Vict.* 23: 5-313.

Baker, G. (1961*a*).—Volumenbeziehungen von wohlerhaltenen Australit-Knöpfen, -Linsen und -Kernen zu ihren primären Formen. *Chem. d. Erde.* 21 (3) (in press).

Baker, G. (1961*b*).—Australite von Wingellina, West-Australien. *Chem. d. Erde.* 21: 118-130.

Baker, G., and Forster, H. C. (1943).—The specific gravity relationships of australites. *Amer. J. Sci.* 241: 377-406.

Barnes, V. E. (1940).—North American tektites. *Univ. Tex. Publ.* No. 3945: 477-582.

Fenner, C. (1955).—Australites Part VI. Some notes on unusually large australites. *Trans. Roy. Soc. S. Aust.* 78: 88-91.